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Comment

Comment on 'The Avogadro constant is not the defining constant of the mole'

Richard J C Brown

National Physical Laboratory, Hampton Road, Teddington TW11 0LW, United Kingdom
University of Surrey, Guildford GU2 7XH, United Kingdom

E-mail: richard.brown@npl.co.uk

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Abstract
The letter provides a short comment on a recent paper in Metrologia, explaining the reasons why the Avogadro constant must be the defining constant of the mole in the International System of Units.

Keywords: Avogadro constant, units, defining constants, mole, amount of substance

1. Discussion

The recent paper by Kacker and Irikura [1] makes a common error, found regularly even in chemistry texts, by treating the mole as simply a name, or identifier, for a very large number of elementary entities. It is not. The two have different dimensions within the International System of Units (SI). The quantity amount of substance, of which the mole is the SI base unit, is assigned an independent dimension in the SI, denoted N. The quantity number of elementary entities has no non-zero dimensional exponents in the SI: it is a quantity with the unit one (also known as a dimensionless quantity, quantity with dimension one, or quantity with dimension number). That is why the dimensioned Avogadro constant (with the unit mol^{-1}) is the defining constant of the mole, and not the Avogadro number, which has no non-zero dimensional exponents in the SI.

The decision to include the mole as a base unit of the International System of Units (SI) in 1971 was not essential but it was extremely useful, especially for chemists, as it had many benefits [2]. The most important was that it introduced the concept of amount of substance having its own independent dimension within the SI. This made it possible to distinguish 'number of elementary entities' from a pure number, therefore making intensive and extensive quantities in chemistry dimensionally distinct—such as molar volume in $\mathrm{m}^3\ \mathrm{mol}^{-1}$ in contrast to the volume of a mole in m^3—and extending the power of dimensional analysis and quantity calculus to chemistry. This provided a clear basis for distinguishing between amount of substance and the quantity number of elementary entities. These important benefits have been elaborated previously [2, 3].

In the SI, following the 2019 revision, the Avogadro Constant is the dimensioned constant of proportionality (sometimes referred to as a concept synthesiser [2]) linking the quantity number of elementary entities (with the unit one, symbol 1) and amount of substance (with the unit mole, symbol mol). This makes it clear that the mole is not simply a number. This also makes it clear that the Avogadro constant is not simply a dimensionless conversion factor between different identifiers for collections of *elementary* entities, such

as we might use to convert between different identifiers for collections of *non-elementary* entities: '12 eggs = 1 dozen eggs' (or even between different units of the same dimensioned quantity such as '1000 m = 1 km'). Suggesting that the dimensionless Avogadro number is all that is needed to define the mole is incorrect because it fails to recognise that amount of substance possesses an independent dimension in the SI.

It is true to say that the defining constants of the SI have different characteristics. The SI Brochure makes this clear [4]. Moreover, the SI places no requirements on the characteristics of defining constants. The defining constants include fundamental constants, constants of proportionality, a technical constant, and an atomic property. (Prior to 2019, specified properties of materials and physical artefacts were also used as defining constants [5].) Regardless of their nature, they all serve as suitable and practical defining constants.

2. Conclusion

The quantity amount of substance, of which the mole is the SI base unit, is assigned an independent dimension in the SI and therefore, by definition, the Avogadro constant must be the defining constant of the mole.

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ORCID iD

Richard J C Brown 0000-0001-6106-0996

References

[1] Kacker R N and Irikura K K 2025 The Avogadro constant is not the defining constant of the mole *Metrologia* **62** 013003
[2] Brown R J C and Brewer P J 2020 What is a mole? *Metrologia* **57** 065002
[3] Brown R J C 2018 The evolution of chemical metrology: distinguishing between amount of substance and counting quantities, now and in the future *Metrologia* **55** L25–33
[4] International Bureau of Weights and Measures 2025 *The International System of Units (SI)* 9th edn (BIPM) (https://doi.org/10.59161/AUEZ1291)
[5] Brown R J C 2024 On the distinction between SI base units and SI derived units *Metrologia* **61** 013001